Claims

[1] I claim:

1. An improved CZ system for growing a single crystal ingot from a molten crystalline feedstock comprising:
a low aspect ratio, wide diameter crucible including a base and side walls for holding a quantity of molten material at a melt / crystal interface with respect to a seed crystal for growing an ingot from the molten material;
a pre melter for providing a substantially continuous source of molten crystalline feedstock to the crucible, such that the melt /crystal interface is maintained at a desired level without vertical travel of the crucible;
annular heating means disposed beneath the base of the crucible for providing a uniform thermal distribution across the melt and at the crystal melt interface for optimal crystal growth .

2. An improved CZ system as in claim 1 wherein the annular heating means comprise a plurality of separately controlled resistive heaters disposed in a radial pattern to establish corresponding thermal zones across the melt, each thermal zone controlled by thermal output of a respective resistive heater such that an optimal thermal distribution is established across the melt and at the crystal melt interface.

3. An improved CZ system as in claim 1, further comprising one or more individually controlled side wall heaters and one or more sensors for monitoring temperature of each thermal zone and for producing signals representative of sensed temperature;
control means responsive to the sensor signals for activating each side wall heater and annular heating means such that an optimal thermal distribution is established across the melt and at the crystal melt interface.

4. An improved CZ grower as in claim 1 further comprising a plurality of crystal pull chambers sequentially disposed with respect to the crucible, each pull chamber including means for positioning a seed crystal at the melt / crystal interface and for pulling the growing ingot, such that upon completion of growth of a first ingot, a first pull chamber moves the first ingot away from the crucible for cooling, and a successive pull chamber moves to position a new crystal at the crystal / melt interface in the crucible.

5. An improved CZ system according to claim 1 wherein the low aspect ratio (diameter with respect to height) of the crucible is in a range of 4:1 to 10:1 and preferably about 8:1.

6. A system for continuous growth of a single crystal ingot as in claim 1 further comprising a means for adding amounts of dopant material to the pre melter such that a dopant concentration throughout the ingot is substantially uniform, axially and radially.

7. An improved CZ system as in claim 1 or 5 further comprising:
a low aspect ratio, wide diameter crucible having interior surfaces for containing the molten material coated with a material selected from the group consisting of: alpha or beta sintered silicon carbide, tantalum nitride, or similar ceramic.
8. An improved CZ system as in claim 1 or 5 further comprising:
a low aspect ratio, wide diameter crucible comprising a material selected from the group consisting of: alpha or beta sintered silicon carbide, tantalum nitride, or similar ceramic.
9. A system for continuous growth of a single crystal ingot comprising:
a low aspect ratio, large diameter crucible including a base for holding a melt of crystalline material ;
a pre-melter having an inlet for receiving a supply of crystalline material, a means for melting the material, and an outlet communicating with the crucible for replenishing the melt as it is taken up by the growing crystal, such that the melt in the crucible is maintained at a desired level with respect to the crystal, without vertical travel of the crucible;
multiple crystal pull chambers sequentially disposed with respect to the crucible such that upon growth of a first ingot, a first pull chamber moves the first ingot out of the away crucible for cooling, and a successive pull chamber moves to position a new crystal in the crucible;
individually controllable heating means disposed adjacent to the base of the crucible for providing an optimal thermal distribution across the melt and at the crystal melt interface for improved crystal growth .
10. A system for continuous growth of a single crystal ingot as in claim 9 further comprising a weir disposed in the melt between the crystal /melt interface and outlet port of the pre-melter; the weir including a top surface extending above the melt to block formation of ripples or thermal perturbations in the melt as molten material from the pre-melter is distributed into the melt.
11. An improved CZ system for growing a single crystal ingot from a molten crystalline feedstock comprising:
a low aspect ratio, wide diameter crucible for holding a quantity of molten material at a melt / crystal interface with respect to a seed crystal for growing an ingot from the molten material;
a pre melter for receiving a source of solid crystalline feedstock and dopant, and providing a substantially continuous source of molten doped crystalline feedstock to the crucible;
individually controllable heating means disposed around the sides and adjacent to the base of the crucible for providing an optimal thermal distribution across the melt and at the crystal melt interface for improved crystal growth .
12 . In a CZ system for growing a single crystal ingot from molten crystalline

feedstock, the improvement comprising:
a low aspect ratio, wide diameter crucible for containing the molten crystalline feedstock, the crucible comprising a material selected from the group consisting of: alpha or beta sintered silicon carbide, or similar ceramic.

13. In a CZ system for growing a single crystal ingot from a molten crystalline feedstock, the improvement comprising:
a low aspect ratio, wide diameter crucible having interior surfaces for containing the molten feedstock coated with a material selected from the group consisting of: alpha or beta sintered silicon carbide, tantalum nitride, or similar ceramic.

14. An improved CZ system for growing an ingot from a seed crystal positioned at a growth interface in a crucible including a pre melter for melting solid crystalline feedstock received from a source and for and providing an output of molten crystalline feedstock to the crucible, comprising;
a load cell means for sensing the weight of the melt in the crucible and for producing output signals representative of the sensed weight;
a level controller comprising a microprocessor responsive to signals from the load cell and for determining output of the pre melter based on a desired depth D of melt in the growth crucible
a flow control means, communicatively linked with the level controller and disposed between the source of solid feedstock and the pre melter for truncating or dispensing feedstock from the source to the pre melter in response to a signal from the level controller such that the output of the pre melter maintains the level of melt in the crucible at a predetermined depth for optimal crystal growth

15. A process for improved growth of a single crystal ingot from a seed crystal positioned at a crystal / melt interface in a molten material comprising:
containing the molten material in a low aspect ratio, wide diameter crucible for reducing convection currents and thermal variations in the melt;
melting solid crystalline material in a pre melter for providing a substantially continuous replenishment of molten material to the crucible for maintaining the crystal / melt interface at a desired level in the crucible;
providing a plurality of heaters beneath the crucible for establishing corresponding thermal zones across the melt;
controlling the thermal output of the heaters for providing an optimal thermal distribution across the melt and at the crystal / melt interface for improved crystal growth .

16. A process according to claim 15 wherein the step of providing substantially continuous replenishment of molten material to the crucible for maintaining the crystal / melt interface at a desired level further comprises:
determining the weight of the crucible both empty and with a desired depth of melt in the crucible;

sensing the actual weight of the growth crucible during crystal growth; and controlling the output of the pre-melter based on a difference between the actual weight of crucible and melt during crystal growth and the determined weight of the crucible with a desired depth of melt by actuating a dispenser for releasing a predetermined amount of solid crystalline feedstock into the pre melter to maintain the desired depth of melt in the crucible.

17. An improved single crystal material characterized by high minority carrier lifetime, made by the process comprising:

growing the single crystal material from a seed crystal held at a crystal melt interface in a wide diameter, low aspect ratio crucible for preventing formation of convection currents and minimizing oxygen in the melt;

melting crystalline feedstock in a pre melter for perturbation free replenishment of the melt in the crucible ;

providing a plurality of individually controllable thermal zones across the melt; such that an optimal thermal distribution is created across the melt, and particularly at the melt crystal interface .

18. In a system for growing an ingot from a crystal positioned at a crystal melt interface in a molten material contained in a crucible having a controlled atmosphere, the improvement comprising:

a pre melter disposed within the controlled atmosphere of the crucible for providing a continuous source of molten crystalline feedstock to the crucible, such that the crystal melt interface is maintained at a desired level with respect to the growing ingot without vertical travel of the crucible;

the pre melter comprising a melting chamber including a first section having an inlet for receiving the source of solid crystalline feedstock and a second section including an outlet having an exit end positioned substantially at the level of the melt in the crucible for providing perturbation free distribution of the molten feedstock to the crucible; and

a heater provided adjacent the melting chamber for melting the solid crystalline feedstock ; and

a weir positioned in the melting chamber, for defining the first and second sections, such that the second section is filled upward from the bottom of the first section to thereby prevent any unmelted, solid crystalline feedstock from passing to the crucible.

19. A system as in claim 18 further comprising:

control means responsive to the level of the crystal melt interface in the crucible and having a connection to the source of solid crystalline feedstock for controllably dispensing the solid crystalline feedstock into the pre melter such that the depth of molten material in the crucible is maintained at a desired level for optimal crystal growth; and

wherein the outlet of the melting chamber comprises a second weir having an inlet and outlet for providing continuous replenishment of molten feedstock into the crucible.

20. A system as in claim 19 wherein the second weir comprises a tube characterized by an inner diameter of a sufficient size to overcome the effect of surface tension and / or minimize thermal perturbations while maintaining replenishment of molten feedstock into the crucible.

21. A pre melter for providing a continuous flow of molten crystalline feedstock to a crucible for growing an ingot at a crystal melt interface therein comprising:
a melting chamber having an inlet for receiving a source of solid crystalline feedstock and an outlet having a distal end positioned substantially at the level of the crystal melt interface for providing substantially continuous replenishment of molten crystalline feedstock to the crucible;
a heater adjacent the melting chamber for melting the molten crystalline feedstock ;
a weir, provided in the melting chamber between the inlet and outlet for directing molten crystalline feedstock to flow downward beneath the weir and upward into the outlet, thereby preventing unwanted solid crystalline feedstock, by virtue of a density lower than molten feedstock, from passing through the outlet to the crucible.

22. An apparatus according to claim 21 further comprising:
means for sensing the weight of molten material in the crucible corresponding to an optimal level of the crystal melt interface with respect to ingot growth;
control means having an input responsive to the means for sensing and an output lead connected to the source of solid crystalline feedstock for controllably dispensing solid crystalline feedstock to the pre melter, such that optimal ingot growth is maintained in the crucible.

23. An improved process for substantially uniform melting of a charge of crystalline feedstock including solid chunks, rods, or granules characterized by a major dimension on the order of down to 1mm or less in a crucible comprising:
containing the crystalline feedstock in a crucible characterized by a low aspect ratio and wide diameter base;
providing a plurality of independently controllable heaters beneath the base of the crucible to establish a plurality of controllable thermal zones across the crucible, such that heat
is driven uniformly into the granules due to higher surface area of contact and shorter thermal path into the charge in the crucible;
activating each heater such that a thermal output of each heater provides an optimal temperature distribution through the charge for melting the granules uniformly and at a rapid rate;

determining the optimal temperature distribution by measuring power consumption of each heater with respect to time needed to achieve the uniform melting of granules at a rapid rate; and

controlling each heater by applying power thereto in accordance with the measured power consumption.

24. An apparatus for substantially uniform melting a charge of crystalline feedstock including solid chunks, rods, or granules characterized by a major dimension on the order of down to 1mm or less in a crucible comprising:

a low aspect ratio, wide diameter crucible for holding the molten crystalline feedstock;

a plurality of independently controllable heaters provided beneath the base of the crucible for establishing corresponding thermal zones across the molten crystalline feedstock in the crucible, such that heat is driven uniformly into the granules due to higher surface area of contact and shorter thermal path into the charge in the crucible including solid material;; and

means for applying power to thermally activate each heater to achieve an optimal temperature distribution such that the thermal zones drive heat uniformly into the solid material at a desired rate.

25. An apparatus according to claim 24 further comprising:

control means for monitoring power consumption of each heater needed to achieve the optimal temperature distribution and for applying power to thermally activate each heater in accordance with the monitored power consumption to achieve a repeatable state wherein granules melt uniformly at a desired rate.

26. An apparatus according to claim 24 wherein the low aspect ratio, diameter with respect to height, of the crucible is in a range of 4:1 to 10:1 and preferably about 8:1.

27. An apparatus for substantially uniform melting of a charge of silicon or polysilicon crystalline material including solid chunks, rods, or granules down to a major dimension on the order of 1mm or less in a crucible comprising:

a low aspect ratio, wide diameter crucible for holding the silicon or polysilicon melt;

a plurality of independently controllable heaters disposed beneath the crucible for establishing corresponding thermal zones through the melt, such that heat is driven uniformly into a higher surface area of contact and shorter thermal path into the charge in the crucible including solid material;

means for thermally activating each heater to achieve an optimal thermal distribution across the melt such that granules are melted uniformly at a desired rate; and

control means for selectively controlling thermal activation of each heater by monitoring power consumed by each heater to achieve the optimal thermal dis-

tribution across the melt.

28. An apparatus according to claim 27 wherein the low aspect ratio (diameter with respect to height) of the crucible is in a range of 4:1 to 10:1; and most preferably in a range of about 8:1.

29. An improved CZ system for growing a single crystal silicon ingot from a molten silicon material comprising:

a low aspect ratio, wide diameter crucible including a base and side walls for holding a quantity of molten silicon at a melt / crystal interface with respect to a seed crystal for growing the ingot from the molten material;

a pre melter for providing a continuous source of molten silicon feedstock to the crucible, such that the melt /crystal interface is maintained at a desired level without vertical travel of the crucible;

annular heating means disposed beneath the base of the crucible for providing a uniform thermal distribution across the melt and at the crystal melt interface for optimal crystal growth .

30. An improved CZ system as in claim 29 wherein the annular heating means comprise a plurality of separately controlled

resistive heaters disposed in a radial pattern to establish corresponding thermal zones across the melt, each thermal zone controlled by thermal output of a respective resistive heater such that an optimal thermal distribution is established across the melt and at the crystal melt interface.

31. A high purity single crystal ingot characterized by substantially reduced dislocation defects and uniform resistivity or conductivity axially and radially made by the process comprising:

growing the single crystal ingot from a seed crystal held at a crystal/melt interface in a wide diameter, low aspect ratio crucible for preventing formation of convection currents and minimizing oxygen in the melt;

melting crystalline feedstock and providing dopant in a pre melter communicating with the crucible such that a thermally unperturbed replenishment of the melt in the crucible is maintained;

providing a plurality of separately controllable heaters beneath the crucible for establishing controllable thermal zones across the melt and particularly at the crystal melt interface, such that a uniform thermal distribution and is maintained across the radius of the growing ingot.